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Smoky Canyon Mine
Remedial Investigation/Feasibility Study

Preliminary Remediation Goals for Soil and Vegetation

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BW	Body Weight
C	Concentration
COPC	Chemical of Potential Concern
DQO	Data Quality Objectives
ECOC	Ecological Chemical of Concern
EcoSSL	Ecological Soil Screening Level
FSTM-1	Feasibility Study Technical Memorandum #1
HQ	Hazard Quotient
IR	Ingestion Rate
kg	Kilogram
kg/day	Kilogram per day
LOAEL	Lowest Observable Adverse Effect Levels
mg	milligrams
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NOAEL	No Observed Adverse Effect Level
ODA	Overburden Disposal Area
PRG	Preliminary Remediation Goal
RI/FS	Remedial Investigation/Feasibility Study
RMM	Residual Mining Materials
SAP	Sampling and Analysis Plan
SSERA	Site-Specific Ecological Risk Assessment
SSLRA	Site-Specific Livestock Risk Assessment
SUP	Site Use Factor
TRV	Toxicity Reference Value
USEPA	United States Environmental Protection Agency

1.0   INTRODUCTION

This document provides the technical analyses used to develop Preliminary Remediation Goals (PRGs) for soils and vegetation that will protect wildlife receptors at the Smoky Canyon Mine (the Site). As part of their review of the Draft Feasibility Study Technical Memorandum #1 (FSTM-1), the agencies have requested development of soil-based PRGs that are protective of wildlife receptors identified as having a higher potential for exposure resulting in elevated risk in the Final Site-Specific Ecological Risk Assessment (SSERA; Formation 2015). The SSERA concluded that selenium is the primary ecological chemical of concern (ECOC) driving risk estimates and the potential need for risk management decisions at the Site.

Elevated concentrations of selenium were observed primarily in Overburden Disposal Areas (ODAs) at the Site with either no cover (i.e., direct revegetation of overburden) or on reclaimed areas where a relatively thin layer of topsoil was used as a cover. In general, elevated concentrations of selenium in soils and vegetation corresponded with higher exposures and risks. Exposures and risks were considerably lower for northern Sage Valley, where no mining activities have occurred, as well as the Panel A Area 1 and Panel E ODAs, where previous reclamation activities resulted in lower selenium concentrations in surface soils, vegetation, and terrestrial prey tissues, resulting in relatively low population-level risk estimates.

The development of soil-based PRGs is a typical and standard approach as part of a feasibility study and PRGs are typically intended to guide the risk-management decision-making process. As discussed in detail in this document, traditional soil-based PRGs, derived using the exposure model, do not represent the best approach for developing reliable risk-based PRGs for use in decision making at the Site.

Two PRGs are proposed based on selenium concentrations in vegetation; an average selenium concentration in vegetation over a period representing chronic exposure (10 milligrams per kilogram [mg/kg]), and over an acute exposure period (50 mg/kg). In addition, the rationale supporting a soil-ingestion only PRG of 137 mg/kg is presented. These proposed PRGs are in addition to PRGs for livestock which are based on the findings in the Final Site-Specific Livestock Risk Assessment (SSLRA; Formation 2016).

The data and analyses provided in this document are intended to demonstrate that the proposed PRGs are protective of the range of wildlife receptors evaluated in the SSERA and are appropriate for guiding risk management decisions. This document is organized as follows:

- Section 2 provides a summary of the SSERA conclusions and discusses the risks predicted for selenium and the other ECOCs at the Site.

- Section 3 presents the collocated soil and tissue data collected at the Site and evaluates the relationship of selenium concentrations in soil, vegetation, and prey tissue.

- Section 4 discusses the methods used to estimate exposure to wildife receptors using the vegetation-based PRGs and examines the ability of the vegetation-based PRGs to predict risk to widlife receptors.

- Section 5 presents the calculation of a soil-based PRG that can be applicable in situations where remediation activities may alter the exposure pathways for wildlife receptors such that only the soil ingestion pathway is required for analysis.

2.0   SITE-SPECIFIC ECOLOGICAL RISK ASSESSMENT SUMMARY

The Final SSERA for the Site was submitted in December 2015 (Formation 2015).   The terrestrial portion of the SSERA assessed potential risks to populations of a range of ecological receptors inhabiting the Site, riparian areas associated with Site drainages and seeps, and in northern Sage Valley. For the terrestrial resources, the SSERA concluded that selenium is the primary ECOC driving risk estimates and the potential need for risk management decisions at the Site. Other ECOCs for terrestrial resources, identified as a result of risk characterization included cadmium, copper, lead, vanadium, and zinc for both upland and riparian receptors. Chromium, manganese, and molybdenum were identified as ECOCs for riparian receptors only.

In the upland portions of the Site, elevated concentrations of selenium were observed primarily on ODAs with either no cover (i.e., direct revegetation of overburden) or topsoil-only covers. Elevated concentrations of ECOCs in soils corresponded with higher exposures and risks. Exposures and risks were considerably lower for northern Sage Valley, Panel A Area 1, and Panel E; risks were lowest within the Dinwoody cover reclamation type and highest on the ODAs with no cover. For areas of northern Sage Valley that are outside of the Pole Canyon Creek corridor, concentrations of ECOCs are relatively low and may reflect background concentrations.

Copper was the only other ECOC extensively discussed in the conclusions of the SSERA. Highly elevated concentrations of copper detected in several small mammal samples were observed and resulted in exposure estimates that exceeded the toxicity reference values (TRVs) for both the coyote and northern harrier receptors.   The concentrations observed showed no spatial relationship or relationship with copper in surface soils on the reclaimed areas of the Site. Site-wide risks to both the coyote and northern harrier cannot be ruled out, due to these copper concentrations.   However, the copper results in small mammals are anomalously elevated in relation to copper measured in surface soils on the reclaimed areas. Therefore, there is considerable uncertainty in copper-based risk conclusions and further study is recommended prior to making risk management decisions related to copper exposure for carnivorous receptors.   Additional sampling of small mammal tissues in the areas where the suspected anomalous copper results were observed was conducted in 2016 and the additional sampling results will be provided in a separate document.

For the remaining ECOCs, the SSERA concluded that concentrations of cadmium, chromium, lead, manganese, molybdenum, vanadium, and zinc corresponded to exposures that exceed TRVs at some locations. However, elevated exposures for these ECOCs are restricted to small portions of the Site. Therefore, while individual receptors may experience exposures exceeding lowest observable adverse effect levels (LOAELs), overall effects from these chemicals was concluded to be low. As indicated in the Final SSERA, risk management decisions for wildlife should, therefore, be based on the potential risk from selenium exposure. Based on the SSERA

conclusions, terrestrial PRGs are being developed only for selenium, as discussed in detail in the following sections.

3.0   SELENIUM IN EXPOSURE MEDIA

This section provides an analysis of Site-specific data to support the derivation of PRGs for selenium.   The available data are described in Section 3.1 and the relationship between selenium concentrations in collocated soil and concentrations in tissue samples are described in Section 3.2.   Section 3.3 discusses the relationship between selenium concentrations in collocated vegetation samples and concentrations in prey tissue samples.

3.1   Site-Specific Data

Data were collected under the Remedial Investigation/Feasibility Study (RI/FS) Sampling and Analysis Plan (SAP) (Formation 2010), and the investigation was guided by the Data Quality Objectives (DQOs), background information, and the SSERA Work Plan that were presented in the RI/FS Work Plan (Formation 2011).   The data collected for the RI/FS were used to refine the preliminary characterization of the nature and extent, and fate and transport, of RI chemicals of potential concern (COPCs) in the environment and were used to support the SSERA.   A detailed description of the investigations conducted under the RI, as well as data collected, and an evaluation of data quality, is provided in Section 2 of the Final RI Report (Formation 2014).

In the summer of 2010, a total of 58 locations were sampled including ODAs, northern Sage Valley, ODA seep areas, riparian areas, and the Hoopes Spring discharge area.   Samples of surface soil, terrestrial vegetation, terrestrial invertebrate tissue, and small mammal (whole body) tissues were collected from each sampling location.   Together these data provide an excellent source of collocated soil (source) and biological tissue data from across the Site and from both upland and riparian areas.   These data formed the primary data source assessed for terrestrial receptors in the SSERA.   The collocated data collected for all four media types at all locations are provided in Attachment 1.

For the purposes of this analysis, only those data collected from terrestrial sampling locations from the reclaimed and un-reclaimed mining areas were used.   Data collected from locations outside of the actual mined areas were not included, because, while they are valuable for assessing risk to non-mined areas, they are not directly applicable for determining the uptake of selenium from residual mining materials (RMM) and mine reclamation materials and for assessing the need for, and effectiveness of remedial actions.   Because the SSERA concluded that population-level risks to all receptors in all locations outside of the mined area were low, using the data from the mined areas provides the most applicable dataset.   The collocated data from the sampling locations from the mining areas for soil, vegetation, terrestrial invertebrates, and small mammals are provided in Table 1.

3.2   Relationship between Soil and Tissue Selenium

The data collected from the 42 collocated upland sampling locations were first evaluated to determine if statistically significant relationships exist between soil concentrations and tissue concentrations. The data were evaluated using a series of linear regression analyses (NCSS 11 Statistical Software 2016). The results of the linear regression analyses include the calculation of the coefficient of determination (R^2) and a determination regarding the statistical significance of the relationship between the two variables (p). The R^2 value is a measure of the amount of variability in selenium concentrations measured in the tissue media (dependent variable) due to the variability in selenium concentrations measured in the surface soil (independent variable). A perfect correlation between the two variables would be represented by an R^2 value equal to 1 and the closer the R^2 value is to 1, the more highly correlated the dependent variable is to the independent variable.

As a first step, regressions between surface soil selenium concentrations and selenium concentrations in vegetation, invertebrates, and small mammals were calculated (Table 2). Using untransformed data, only the relationship between soil and plant selenium concentration showed a significant correlation ($p < 0.1$) between the two variables. Terrestrial invertebrate and small mammal selenium concentrations were not correlated with the surface soil selenium concentration. When the data were transformed using a standard natural logarithm transformation, all three variables were significantly correlated, but the R^2 ranged from 0.47 for small mammals to 0.65 for vegetation indicating a marginal relationship between soil selenium concentrations and selenium concentrations in collocated tissue samples. The regression plots for all of the statistical analyses discussed in this section are provided in Attachment 2. The full results and outputs from the statistical analysis are provided in Attachment 3.

Based solely on the results of the regression analyses between soil and tissue concentration, the use of a soil-based PRG would result in considerable uncertainty. This uncertainty is illustrated by Figure 1, which shows the lack of consistency between selenium concentrations in soil and exceedances in the vegetation-based PRG. Vegetation selenium concentrations exceeded 10 mg/kg in samples collocated at soil concentrations as low as 3.6 mg/kg and were less than 10 mg/kg in samples with collocated soil concentrations as high as 42.9 mg/kg. This lack of consistency in the relationship between selenium concentrations in soil and selenium concentrations in vegetation could result in significant unexpected results if a PRG were to be developed based on the relationship between soil, vegetation, and prey tissue selenium concentrations.

3.3   Relationship between Vegetation and Invertebrate/Small Mammal Tissue Selenium

Using the same approach as discussed in the previous section for soil, the correlation between selenium concentrations in vegetation (independent variable) and prey tissues (dependent variables) was also evaluated.

Terrestrial invertebrates are likely to be exposed to selenium via both exposure to surface soil and via exposure to live plant material as well as plant detritus. Small mammals are likely to be exposed to selenium via similar pathways as well as exposure via ingestion of invertebrate tissues. In both cases, exposure to selenium in soils is most likely much lower than exposure to selenium in the food eaten by both groups of animals. As a result, the regression analyses comparing terrestrial invertebrates and small mammals as dependent variables to terrestrial plants was also conducted (Table 2). In both cases, the R^2 values calculated showed stronger correlations between vegetation and invertebrate ($R^2 = 0.85$) and between vegetation and small mammal tissue ($R^2 = 0.76$) selenium concentrations than the soil-based regressions. A regression analysis was also run between small mammal and invertebrate tissues which resulted in a very similar R^2 value ($R^2 = 0.79$) to the vegetation to small mammal regression.

Based on these analyses, the relationships in selenium concentrations between terrestrial vegetation and invertebrate and small mammal tissues provide a better method for estimating exposure for terrestrial wildlife receptors via these pathways. These relationships can be used to support the development of selenium PRGs for the Site. The details of the estimates of exposure for terrestrial wildlife receptors using the proposed vegetation-based PRGs are provided in the following sections.

4.0   VEGETATION-BASED PRG FOR SELENIUM

Two vegetation-based selenium PRGs in terrestrial vegetation are proposed. The 10 mg/kg PRG is based on Site-wide average selenium concentrations in vegetation, whereas the 50 mg/kg PRG is applied to individual locations as a do not exceed value.

The 10 mg/kg PRG represents an average vegetation concentration that would be protective of chronic adverse effects to sub-populations of wildlife receptors that may inhabit the mined areas of the Site for all or part of the time. This PRG is above the level identified to be protective of chronic adverse effects to grazing animals including livestock and wild ungulates (5 mg/kg) in the Final Site-Specific Livestock Risk Assessment (SSLRA; Formation 2016). However, the livestock PRG is applied to a grazing allotment area.

The 50 mg/kg PRG is based on acute mortality effects to cattle, sheep, and pigs (Merck 2008). This benchmark was used as the acute benchmark in the SSLRA. Acute selenium risk is usually due to ingestion of dietary vegetation in excess of 50 mg/kg and is typically observed when selenium hyper-accumulating plants are the primary vegetation types available to the grazers. Acute selenium poisoning results in death typically within a few hours and differs from sub-chronic effects which are characterized by neurologic abnormalities. The acute PRG would be considered to be a not-to-exceed benchmark for selenium in terrestrial vegetation due to the potential for significant acute effects if the vegetation were consumed.

The protectiveness of the 10 mg/kg PRG to the range of wildlife receptors at the Site is discussed in detail in the following sections. In Section 4.1, the regression models developed in Section 3 are used to estimate prey tissue concentrations at the PRG concentrations and those predicted concentrations are used to estimate exposure via SSERA exposure pathways in Section 4.2.   Hazard quotients (HQs) are calculated in Section 4.3 using the estimated exposures and TRVs from the SSERA. The expected protectiveness of the PRG is discussed in Section 4.4 and the accuracy of the predicted exposure and HQs is discussed in Section 4.5.

4.1   Estimating Prey Tissue Concentrations from Vegetation

Because the goal of the PRG is to be protective of a range of wildlife receptor populations, demonstrating the effectiveness of a vegetation-based PRG is necessary. Table 3 provides the linear equations calculated in the regressions discussed in the previous section. Using the equations shown in Table 3, predicted invertebrate and small mammal tissue concentrations are calculated using the PRGs as target vegetation concentrations in Table 4. The predicted prey tissue concentrations shown represent mean selenium concentrations predicted by the linear regression models at the target vegetation selenium concentrations. Based on the statistical analyses provided in Attachment 3, the mean concentration of prey tissues predicted within areas containing mean vegetation selenium concentrations equal to the target concentrations

shown in Table 4 are expected to be within the bounds of the 95% confidence limits of the linear regression models (Attachment 2).

4.2   **Exposure Estimation**

Quantification of exposure requires not only data on selenium concentrations in Site environmental media but also estimates of predicted ingestion rates and contact information for each receptor and pathway. All exposure factors such as body weights, ingestion rates of food, proportions of prey ingested, and home range used for each receptor was provided in detail in Section 2.7 and in Tables 2-14 (feeding habits) and 2-15 (exposure parameters) of the Final SSERA. The values from those tables were used in this document as shown in Table 5.

The exposure model provided in the SSERA was used to estimate exposure to a subset of SSERA receptors. The receptors were chosen to provide a range of feeding habits and home range sizes for this analysis. The generic exposure equation is:

$$\text{Dose}_{\text{Total}} = (\text{SUF}) \times \frac{\left[\left(C_{\text{media}} \text{ x } IR_{\text{media}}\right) + \left(C_{\text{prey}}\right)\left(IR_{\text{prey}}\right)\right]}{BW}$$

Where:

$\text{Dose}_{\text{Total}}$=   Daily dose resulting from ingestion of abiotic media and dietary items (milligrams chemical per kilogram body weight per day [mg chemical/kg BW/Day]).

C_{media} =   Concentration of chemical in abiotic media (mg/kg or milligrams per liter [mg/L]) during incidental ingestion of that media.

C_{prey} =   Measured concentration of chemical in prey or forage types (mg/kg).

IR   =   Ingestion Rate (the amount of prey items, surface water, sediment, and soil ingested per day) (kilogram per day [kg/day], kg/kg BW/day).

BW   =   Body Weight of receptor species (kg).

SUF   =   Site Use Factor to account for the amount of time that the organism spends using the Site.

For the initial calculations in each tier, the SUF was assumed to be 1.0 for all receptors and soil ingestion was assumed to be insignificant (discussed in more detail in Section 3.2). Water ingestion was determined to be a minor contributor to exposure and risk in the SSERA and is not discussed further in this analysis.

As shown in Table 5, exposure via the food ingestion pathway was estimated for five receptors representative of a range of exposure types and home range sizes across a range of mean vegetation concentrations.

4.3   **Hazard Quotient Calculation**

As defined in the SSERA, HQs are a standard approach identified in United States Environmental Protection Agency (USEPA) guidance (1997) to make comparisons between the predicted exposure for a receptor and the exposure rate indicative of some level of toxicity to the receptor (TRV). Therefore, the HQ is simply a ratio of the estimated exposure concentration to the TRV where:

$$HQ = \text{Intake/TRV}$$

For selenium, the SSERA risk characterization used the geometric mean of the no observed adverse effect level (NOAEL) TRV presented in the Ecological Soil Screening Level (EcoSSL; USPEA 2007) document as a less conservative and potentially more representative TRV for consideration in risk management decision making. The traditional NOAEL TRV assessed in the Final SSERA provides little value in PRG calculation as it is indicative of a true no effect level which is likely to be overly-conservative in predicted population-level effects. Similarly, the lowest LOAEL TRV was also evaluated in the SSERA but again provides only limited value to the PRG calculation because it is predictive of only a limited potential of effects to the most sensitive species studied.

The geometric mean NOAEL TRVs from the EcoSSL guidance were discussed in the SSERA and provide an estimate of the mean exposure rate across all of the sub-lethal growth and reproduction endpoints in the database across species and studies. As presented in the SSERA, the geometric mean NOAEL TRVs may provide risk managers with a better estimate of the average exposure rate across species that have been shown to have no effects, but because the TRV is higher than the lowest LOAEL, some level of effects are possible at or below the TRV. However, those effects are not expected to correspond to significant population-level effects. A full discussion of the underlying data used to calculate the geometric mean TRVs was provided in Section 4.3.4 of the SSERA and, as discussed in that document, the geometric mean NOAEL is still conservative; other factors including habitat and site use are much more important determinants of whether ecologically meaningful adverse impacts on a population are expected.

Using the exposure estimated in Table 5, HQs were calculated for the five receptors using the geometric mean TRVs across the range of target vegetation concentrations listed in Table 6. These HQs represent the exposure from the food ingestion pathway only.

Because it was considered in the EcoSSL document, the soil ingestion pathway must also be considered as part of the exposure calculations. In Table 7, the regression equation presented in Table 2 for predicting vegetation concentrations from soil selenium concentrations was used to back-calculate soil concentrations at the range of target vegetation concentrations. To do the calculations, the linear regression equation was solved for soil concentration as shown in Table 7.

Using the predicted mean soil concentrations, the estimated exposure for each receptor due to soil ingestion was calculated and is shown in Table 8. The soil ingestion rates used were taken from the Final SSERA. In Table 9, the predicted exposure from both food and soil were summed and used to calculate HQs.

Because the exposure via the soil ingestion pathway is small, the HQs calculated using the food only and the food plus soil ingestion pathways are compared in Table 10. In all cases, HQs were increased by an insignificant amount (less than 1% to less than 3%) when the soil ingestion pathway is included in the PRG calculations. Based on this result, it is suggested that PRG calculations be conducted using the food ingestion pathway only.

The data provided in Table 11 also show that area use is an important consideration in PRG development, especially when considering animals with large home ranges. In the case of the small home range receptors such as the deer mouse and American robin receptors, home range size is small enough that entire sub-populations of the regional populations may reside entirely within the mine panels assessed at the Site.

For the large home range receptors, population-level exposure is low. As shown in Table 2-17 of the Final SSERA, home ranges for individual coyotes (7,240 acres) and northern harriers (642.5 acres) are very large relative to the size of the mine panels. The home range for a mule deer herd was estimated at 31,424 acres. The largest of the mine panels assessed in the Final SSERA is 392 acres (Panel E) or approximately half of the home range for an individual northern harrier and approximately 1% of the range for mule deer. This indicates that for large home range receptors, the mine panels represent habitat for only a portion of the activity for one or several individuals of the local populations and are not large enough to support populations or even sub-populations of these receptors for more than periodic feeding.

HQs calculated for the large home range receptors at the target vegetation selenium concentrations, while taking site use into consideration, are provided in Table 11.

4.4   Evaluating the Protectiveness of Vegetation-Based PRGs

As indicated in Table 6, HQs for the small home range receptors, assuming an average vegetation concentration equal to 10 mg/kg, would be expected to be equal to approximately 7 for the deer mouse receptor and 5 for the American robin receptor. These HQs are marginally higher than those calculated for the northern Sage Valley exposure area in the SSERA where HQs for the deer mouse and American robin receptors were approximately equal to 2 using the same geometric mean NOAEL TRVs. No significant population level risks were predicted in the SSERA for the northern Sage Valley exposure area. While risks on the mined areas of the Site would be predicted to be higher than in northern Sage Valley, significant population level effects to future sub-populations of small home range receptors inhabiting those areas are unlikely and

the effect on the local receptor populations that make up areas both within and outside of the mined areas are likely to be affected.

For the large home range receptors, HQs would be expected to be less than or equal to 1 for all receptors using a highly conservative 50% area use factor and less than 1 for all receptors at a still conservative 33% area use (Table 11) which would be representative of exposure to one or several individuals and not a population. No effects are predicted to local and regional populations of large home range receptors.

Based on these calculations, the use of a 10 mg/kg Site-wide average vegetation concentration as a PRG would appear to be protective of all terrestrial wildlife receptor populations and sub-populations assessed in the SSERA. Current conditions on the mine panels range from exposed RMM in older mine areas (e.g., Panel D and portions of Panel A) to cover systems placed over RMM (Pole Canyon ODA, portions of Panel A, and Panel E), thus preventing uptake of selenium by vegetation. Remedial actions to address those areas where vegetation currently grows directly in RMM will reduce concentrations and risks to selenium and other ECOCs. Because all ECOCs are associated with the same RMM, selenium-based PRGs and remediation would result in reduced risks to all ECOCs.

4.5   Testing the Predictive Ability of the PRG

In order to test the predictive ability of the vegetation-based PRG model, a subset of upland sampling locations that contained a geometric mean selenium concentration measured in terrestrial vegetation approximately equal to 10 mg/kg was selected from the full upland dataset. The collocated soil and tissue data collected from Panel D (n = 12 locations) were used as a test of the predictive ability of the vegetation-based PRG model. The measured soil and tissue concentrations at those sites are provided in Table 12 along with the measured and predicted geometric mean selenium concentrations in invertebrates and small mammals.

The measured geometric mean and estimated geometric mean concentrations were then used to calculate HQs for the receptors in Table 13. In all cases, the HQs were nearly identical between the measured and predicted concentrations indicating that the vegetation-based PRG model should provide an accurate estimation of risk at average media concentrations that can be expected when the average vegetation selenium concentration is approximately equal to 10 mg/kg. This is despite the large range of soil concentrations observed in the eight samples (1.9 to 42.9 mg/kg).

As a second point of comparison, the soil to tissue models presented in Table 2 were used to estimate plant, invertebrate, and small mammal concentrations at the geometric mean soil concentration measured in the Panel D samples (Table 14). Those concentrations were then used to calculate HQs for the list of receptors (Table 15) in the same manner as for the vegetation-based model discussed above. The HQs for the large home-range receptors were

similar between the measured and estimated media concentrations, but the deer mouse and American robin HQs calculated using the soil-based model were approximately half of the HQs calculated using the measured tissue concentrations. These results again indicate that the use of a vegetation-based PRG will result in more accurate risk estimates than using a more traditional soil-based PRG.

5.0   SOIL INGESTION ONLY PRG

In some cases, it is possible that remediation activities at the regional phosphate mine sites may result in areas without vegetation, for example if chert/limestone is placed at the surface. In those cases, a PRG for selenium which utilizes only the soil ingestion pathway is most appropriate even though terrestrial ecological receptor use of such areas would be severely limited due to a lack of habitat.

Table 16 provides a back-calculation of a soil selenium concentration that results in an HQ equal to 1 from which only the soil ingestion pathway shown in the equations from Section 4.2 are considered. The soil ingestion rate presented in Table 16 was taken from the Final SSERA. As indicated on the table, the deer mouse receptor would have an HQ equal to 1 considering soil ingestion only at a selenium concentration equal to 137 mg/kg in soils. As such, for areas engineered to be without vegetation, selenium concentrations less than 137 mg/kg would be representative of *de minimis* risks to all receptors for the soil ingestion pathway.   This represents a very high soil selenium concentration due to the low significance of the soil ingestion pathway in the overall exposure to the receptors at the Site. As shown in Section 4.2, the soil ingestion pathway makes up from less than 1% to only approximately 3% of the total exposure for receptors.

It is noted that remedial actions being evaluated at the Site will address risks due to selenium levels in vegetation at the surface of ODAs, as well as surface water and groundwater. Therefore, the remedies would be designed to meet PRG for vegetation and soil as well as for other environmental media.

6.0   CONCLUSIONS

The SSERA assessed potential risks to populations of terrestrial ecological receptors inhabiting the Site, riparian areas associated with Site drainages and seeps, and in northern Sage Valley. The assessment concluded that selenium is the primary ECOC and drove the risk estimates and the potential need for risk management decisions at the Site. Other ECOCs identified in the terrestrial SSERA as a result of risk characterization included cadmium, copper, lead, vanadium, and zinc for both the upland and riparian receptors. Chromium, manganese, and molybdenum were identified as ECOCs for riparian receptors only.

For those ECOCs, the SSERA concluded that concentrations present at the Site corresponded to exposures that exceed TRVs at some locations, but elevated exposure for the non-selenium ECOCs is restricted to small portions of the Site. While individual receptors may experience exposures exceeding LOAELs for those ECOCs, overall effects on populations was concluded to be low. Risk management decisions for wildlife should, therefore, be based on the potential risk from selenium exposure.

Based on the results of this analysis, the use of a vegetation-based PRG is appropriate at the Site and provides a better predictor of future exposure than using a traditional soil-based PRG (except in areas where engineered remediation efforts result in no vegetation cover). The selection of a 10 mg/kg PRG for average selenium concentration in vegetation will result in a level of risk to sub-populations of small home range receptors inhabiting mine panels and ODAs at the Site which is only approximately three times higher than the risk that was calculated in northern Sage Valley in the Final SSERA. The SSERA concluded that risks in the northern Sage Valley were thought to be indicative of background and not expected to cause significant effects to populations and sub-populations of small home range receptors inhabiting the Site and surrounding areas. The 10 mg/kg vegetation PRG is, therefore, also expected to be protective of area populations of large home range receptors that may utilize the Site for occasional or regular feeding activities.

A separate PRG for soil ingestion only was calculated at 137 mg/kg selenium as an average concentration. Remedial actions would need to meet both the soil and vegetation PRGs to be protective.

7.0   REFERENCES

Formation Environmental, LLC (Formation). 2010. Final Sampling and Analysis Plan (Quality Assurance Project Plan [QAPP], Field Sampling Plan [FSP], and Health and Safety Plan [HASP]). Smoky Canyon Mine Remedial Investigation/Feasibility Study (RI/FS). Prepared for J.R. Simplot Company. June.

Formation. 2011. Final RI/FS Work Plan (Rev 03). Smoky Canyon Mine RI/FS. Prepared for J.R. Simplot Company. May.

Formation. 2014. Final Remedial Investigation Report. Smoky Canyon Mine RI/FS. Prepared for J.R. Simplot Company. September.

Formation. 2015. Final Site-Specific Ecological Risk Assessment Report. Smoky Canyon Mine RI/FS. Prepared for J.R. Simplot Company. December.

Formation. 2016. Final Site-Specific Livestock Risk Assessment Report. Smoky Canyon Mine RI/FS. Prepared for J.R. Simplot Company. January.

Merck & Co., Inc. 2008. The Merck Veterinary Manual: Selenium Toxicosis. Merck & Co., Inc. Whitehouse Station, NJ.

NCSS 11 Statistical Software (2016). NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/ncss.

United States Environmental Protection Agency (USEPA). 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. USEPA 540-R-97-006. Environmental Response Team, Edison, NJ.

USEPA 2007. Ecological Soil Screening Levels for Selenium. Interim Final. OSWER Directive 9285.7-72. July, 2007.

TABLES

TABLE 1
Selenium Data from Upland Sampling Location Exposure Media

Sampling Location	Exposure Media (mg/kg)			
	Surface Soil	Terrestrial Vegetation	Terrestrial Invertebrate	Small Mammal[1]
APL-10	245.00	31.60	30.20	28.30
APL-13	6.00	17.50	20.20	23.07
APL-15	46.90	50.10	12.00	10.90
APL-16	1.20	4.08	9.07	14.89
APL-18	39.60	14.10	16.30	16.60
APL-19	4.10	0.37	11.10	2.60
APL-20	0.71	0.08	1.61	11.70
APL-21	5.10	0.43	2.36	2.08
APL-25	0.35	0.11	1.52	2.78
APL-26	3.60	0.62	1.97	2.11
APL-27	2.60	1.50	4.50	1.99
APL-29	0.66	0.03	1.32	0.89
DPL-16	45.60	13.60	34.60	31.10
DPL-18	4.50	2.02	8.77	7.80
DPL-20	5.80	12.20	24.50	36.80
DPL-21	6.80	14.90	26.00	30.40
DPL-23	9.20	29.50	53.80	36.80
DPL-25	7.40	24.80	62.30	53.42
DPL-26	10.80	7.74	32.10	33.30
DPL-27	3.60	28.30	50.10	54.40
DPL-29	18.10	8.81	26.60	23.35
DPL-32	42.90	9.15	16.20	19.07
DPL-33	1.90	5.33	8.45	6.08
DPL-34	4.00	11.80	29.20	48.30
EPL-11	0.46	0.09	5.32	4.05
EPL-12	1.50	0.35	2.27	2.99
EPL-14	1.80	0.34	1.68	1.84
EPL-15	6.80	1.11	3.42	2.97
EPL-18	1.40	0.77	4.41	3.21
EPL-19	0.67	0.33	1.31	2.94
EPL-21	0.94	0.33	7.08	1.52
EPL-22	0.18	0.07	1.09	1.39
EPL-25	0.21	0.30	0.97	3.93
EPL-26	0.54	0.23	1.11	1.28
EPL-27	0.07	0.07	1.07	1.31
EPL-28	0.08	0.04	0.45	1.55
PCO-05	8.40	3.71	20.50	30.10
PCO-06	2.00	8.70	29.30	101.9
PCO-07	1.10	7.02	18.60	54.45
PCO-10	39.20	29.00	27.70	23.90
PCO-12	34.70	6.36	13.60	14.60
PCO-14	5.50	16.00	30.00	36.67

Notes:
mg/kg - milligrams per kilogram
[1]- Small mammal concentrations are averages of concentrations in all animals collected from the site.

TABLE 2
Linear Regression R^2 Value Summary

Soil vs. Media[1]	Untransformed	In Transformed
Terrestrial Vegetation	0.32	0.65
Terrestrial Invertebrate	0.07	0.6
Small Mammal	0.01	0.47
Vegetation vs. Media[2]		
Terrestrial Invertebrate	0.75	**0.85**
Small Mammal	0.36	**0.76**
Invertebrate vs. Small Mammal[3]	0.78	0.79

Notes:

[1] - The soil concentration at sampling location APL-10 was determined to be an outlier. R^2 values presented do not include data from APL-10.

[2] - The vegetation concnetration at sampling location APL-15 was determined to be an outlier. R^2 values presented do not include data from APL-15

[3] - The invertebrate concentration at sampling location PCO-06 was determined to be an outlier. R^2 values presented do not include data from PCO-06

TABLE 3
Linear Equations Selected for Analysis

	Slope (m)	Slope S.E.	Intercept (B)	Intercept S.E.
Plant to Inverterbrate	0.591	0.04	1.678	0.088
Plant to Small Mammal	0.558	0.05	1.833	0.111

Note:

Linear Equation:

ln Tissue = m(ln Plant) + B

TABLE 4
Prey Tissue Concentrations at a Range of Vegetation Concentrations

Target Vegetation Concentration (mg/kg)	In Vegetation	m	B	In Invertebrate (predicted)	Invertebrate (mg/kg Predicted)
10	2.30	0.591	1.678	3.04	20.9
50	3.91			3.99	54.1

Target Vegetation Concentration (mg/kg)	In Vegetation	m	B	In Small Mammal (predicted)	Small Mammal (mg/kg Predicted)
10	2.30	0.558	1.833	3.12	22.6
50	3.91			4.02	55.5

TABLE 5
Receptor Exposure at Predicted Prey Concentrations

Receptor	Percent of Diet			Food Ingestion Rate (mg/kg BW/day)	Exposure at Target Vegetation Concentrations (mg/kg BW/day)	
	Vegetation	Invertebrate	Small Mammal		10	50
Deer Mouse	55%	46%	0%	0.21	3.14	10.89
American Robin	50%	50%	0%	0.21	3.24	10.93
Mule Deer	100%	0%	0%	0.04	0.40	2.00
Coyote	4%	6%	90%	0.03	0.73	1.82
Northern Harrier	0%	3%	98%	0.10	2.26	5.54

Note:

Assumes 100% Site Use

TABLE 6
Hazard Quotients at Predicted Prey Concentrations
(assumes food exposure only)

Receptor	Exposure at Target Vegetation Concentrations (mg/kg BW/day)		Toxicity Reference Value (mg/kg BW/day)	Hazard Quotients at Target Vegetation Concentrations	
	10	50		10	50
Deer Mouse	3.14	10.89	0.437	7.2	25
American Robin	3.24	10.93	0.610	5.3	18
Mule Deer	0.40	2.00	0.437	0.9	4.6
Coyote	0.73	1.82	0.437	1.7	4.2
Northern Harrier	2.26	5.54	0.610	3.7	9.1

Notes:

Assumes 100% Site Use

Mammal TRV = 0.437 mg/kg BW/day

Avian TRV = 0.61 mg/kg BW/day

TABLE 7
Estimating Soil Concentration at Given Plant Concentrations

Target Vegetation Concentration (mg/kg)	In Vegetation	m	B	In Soil (predicted)	Soil (mg/kg Predicted)
10	2.30	1.025	-0.473	2.71	15.00
50	3.91			4.28	72.10

Notes:

Solve for lnSoil:

lnVeg = m(lnSoil)+B

lnSoil = -B+lnVeg/m

TABLE 8
Predicted Exposure Via Soil Ingestion Pathway

Receptors	Soil Ingestion Rate (mg/mg BW/day)	Soil Concentration Predicted at Target Vegetation Concentrations (mg/kg)		Exposure at Target Vegetation Concentrations (mg/kg BW/day)	
		10	50	10	50
Deer Mouse	0.0032			0.048	0.231
American Robin	0.0027			0.040	0.195
Mule Deer	0.0003	15.0	72.1	0.004	0.022
Coyote	0.0009			0.013	0.065
Northern Harrier	0.0007			0.010	0.050

Note:

Assumes 100% Site Use

TABLE 9
Total Predicted Exposure and Hazard Quotients

Receptors	Predicted Food Expsosure at Target Vegetation Concentrations (mg/kg BW/day)		Predicted Soil Exposure at Target Vegetation Concentrations (mg/kg BW/day)		TRV (mg/kg BW/day)	Sum HQ at Target Vegetation Concentrations	
	10	50	10	50		10	50
Deer Mouse	3.14	10.89	0.0480	0.2307	0.437	7.3	25.4
American Robin	3.24	10.93	0.0405	0.1947	0.610	5.4	18.2
Mule Deer	0.40	2.00	0.0045	0.0216	0.437	0.9	4.6
Coyote	0.73	1.82	0.0135	0.0649	0.437	1.7	4.3
Northern Harrier	2.26	5.54	0.0105	0.0505	0.610	3.7	9.2

Note:

Assumes 100% Site Use

Preliminary Remediation Goal Analysis
Smoky Canyon Mine RI/FS

TABLE 10
Percent Change in HQ With Soil Ingestion

Receptors	Sum HQ at Target Vegetation Concentrations		HQ for Food Pathway Only at Target Vegetation Concentrations		% Increase of HQ with Soil Pathway at Target Vegetation Concentrations	
	10	50	10	50	10	50
Deer Mouse	7.2943892	25.4421	7.1845672	24.914127	1.5%	2.1%
American Robin	5.381922	18.230276	5.3155393	17.91114	1.2%	1.8%
Mule Deer	0.9256276	4.6261565	0.9153318	4.576659	1.1%	1.1%
Coyote	1.6915094	4.31462	1.6606219	4.1661278	1.8%	3.4%
Northern Harrier	3.7146942	9.170973	3.6974839	9.0882339	0.5%	0.9%

Note:

Assumes 100% Site Use

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1 of 1

TABLE 11
Effect of Area Use

Receptors	Individual Home Range (acres)	HQ with 10% Area Use at Target Vegetation Concentrations	
		10	50
Deer Mouse	0.23	N/A - Assumes that sub-populations of animals may exist entirely within each EU	
American Robin	0.395	N/A - Assumes that sub-populations of animals may exist entirely within each EU	
Mule Deer [1]	31424	0.09	0.5
Coyote	7240	0.2	0.4
Northern Harrier	643	0.4	0.9

Receptors	Individual Home Range (acres)	HQ with 33% Area Use at Target Vegetation Concentrations	
		10	50
Deer Mouse	0.23	N/A - Assumes that sub-populations of animals may exist entirely within each EU	
American Robin	0.395	N/A - Assumes that sub-populations of animals may exist entirely within each EU	
Mule Deer [1]	31424	0.30	1.5
Coyote	7240	0.5	1.4
Northern Harrier	643	1.2	3.0

Receptors	Individual Home Range (acres)	HQ with 50% Area Use at Target Vegetation Concentrations	
		10	50
Deer Mouse	0.23	N/A - Assumes that sub-populations of animals may exist entirely within each EU	
American Robin	0.395	N/A - Assumes that sub-populations of animals may exist entirely within each EU	
Mule Deer [1]	31424	0.46	2.3
Coyote	7240	0.8	2.1
Northern Harrier	643	1.8	4.5

Note:

1 - Mule deer home range may be representative of a herd.

TABLE 12
Real-World Testing - Subset of Sites at Smoky with Geomean Vegetation
Concentration Near 10 mg/kg. Actual vs. Estimated Tissue Concentrations

Location	Soil Concentration (mg/kg)	Terrestrial Vegetation (mg/kg)	Terrestrial Invertebrates (mg/kg)	Small Mammals (mg/kg)
DPL-16	45.60	13.60	34.60	31.10
DPL-18	4.50	2.02	8.77	7.80
DPL-20	5.80	12.20	24.50	36.80
DPL-21	6.80	14.90	26.00	30.40
DPL-23	9.20	29.50	53.80	36.80
DPL-25	7.40	24.80	62.30	53.42
DPL-26	10.80	7.74	32.10	33.30
DPL-27	3.60	28.30	50.10	54.40
DPL-29	18.10	8.81	26.60	23.35
DPL-32	42.90	9.15	16.20	19.07
DPL-33	1.90	5.33	8.45	6.08
DPL-34	4.00	11.80	29.20	48.30
Actual Geomean	8.42	11.24	26.33	26.62
Estimated Geomean	N/A	N/A	22.37	24.12

Note:

The small mammal seleniun concentration from PCO-06 (101.9 mg/kg)

was determined to be an outlier and was omitted from this analysis.

TABLE 13
Risk Calculations Using Measured and Estimated Tissue Concentrations from Smoky Sites with Geomean Vegetation Concentration Approximately Equal to 10 mg/kg

Receptors	Percent of Diet			Food Ingestion Rate (mg/kg BW/day)	Measured Geomean Tissue Concentration (mg/kg)			Estimated at Plant Geomean Tissue Concentration (mg/kg)			Exposure (mg/kg BW/day)		TRV (mg/kg BW/day)	HQ	
	Vegetation	Invertebrate	Small Mammal		Vegetation	Invertebrate	Small Mammal[2]	Vegetation	Invertebrate	Small Mammal	Measured	Predicted		Measured	Predicted
Deer Mouse	55%	46%	0%	0.21	11.20	26.30	26.60	11.20	22.40	24.10	3.79	3.42	0.437	8.7	7.8
American Robin	50%	50%	0%	0.21							3.94	3.53	0.610	6.5	5.8
Mule Deer [1]	100%	0%	0%	0.04							0.15	0.15	0.437	0.3	0.3
Coyote[1]	4%	6%	90%	0.03							0.28	0.26	0.437	0.6	0.6
Northern Harrier[1]	0%	3%	98%	0.10							0.88	0.79	0.610	1.4	1.3

Notes:

1 - Assumes 33% site use

2 - Excludes outlier small mammal samples from PCO-06

TABLE 14
Predicted Tissue Concentrations Using Soil Models

Soil Concentration (mg/kg)	Plant			Invertebrate			Small Mammal		
	Slope (m)	Intercept (b)	Predicted Concentration (mg/kg)	Slope (m)	Intercept (b)	Predicted Concentration (mg/kg)	Slope (m)	Intercept (b)	Predicted Concentration (mg/kg)
8.42	1.025	-0.4733	5.53	0.597	1.379	14.17	0.473	1.694	14.91

TABLE 15
Risk Calculations Using Measured and Estimated Tissue Concentrations (from Soil) from Smoky Sites with Geomean Vegetation Concentration Approximately Equal to 10 mg/kg

Receptors	Percent of Diet			Food Ingestion Rate (mg/kg BW/day)	Estimated at Soil Geomean (mg/kg)			Exposure (mg/kg BW/day)		TRV (mg/kg BW/day)	HQ	
	Vegetation	Invertebrate	Small Mammal		Vegetation	Invertebrate	Small Mammal	Measured	Predicted		Measured	Predicted
Deer Mouse	55%	46%	0%	0.21	5.53	14.20	14.90	3.79	1.99	0.437	8.7	4.6
American Robin	50%	50%	0%	0.21				3.94	2.07	0.610	6.5	3.4
Mule Deer [1]	100%	0%	0%	0.04				0.15	0.07	0.437	0.3	0.2
Coyote [1]	4%	6%	90%	0.03				0.28	0.16	0.437	0.6	0.4
Northern Harrier [1]	0%	3%	98%	0.10				0.88	0.49	0.610	1.44	0.8

Notes:

1 - Assumes 33% site use

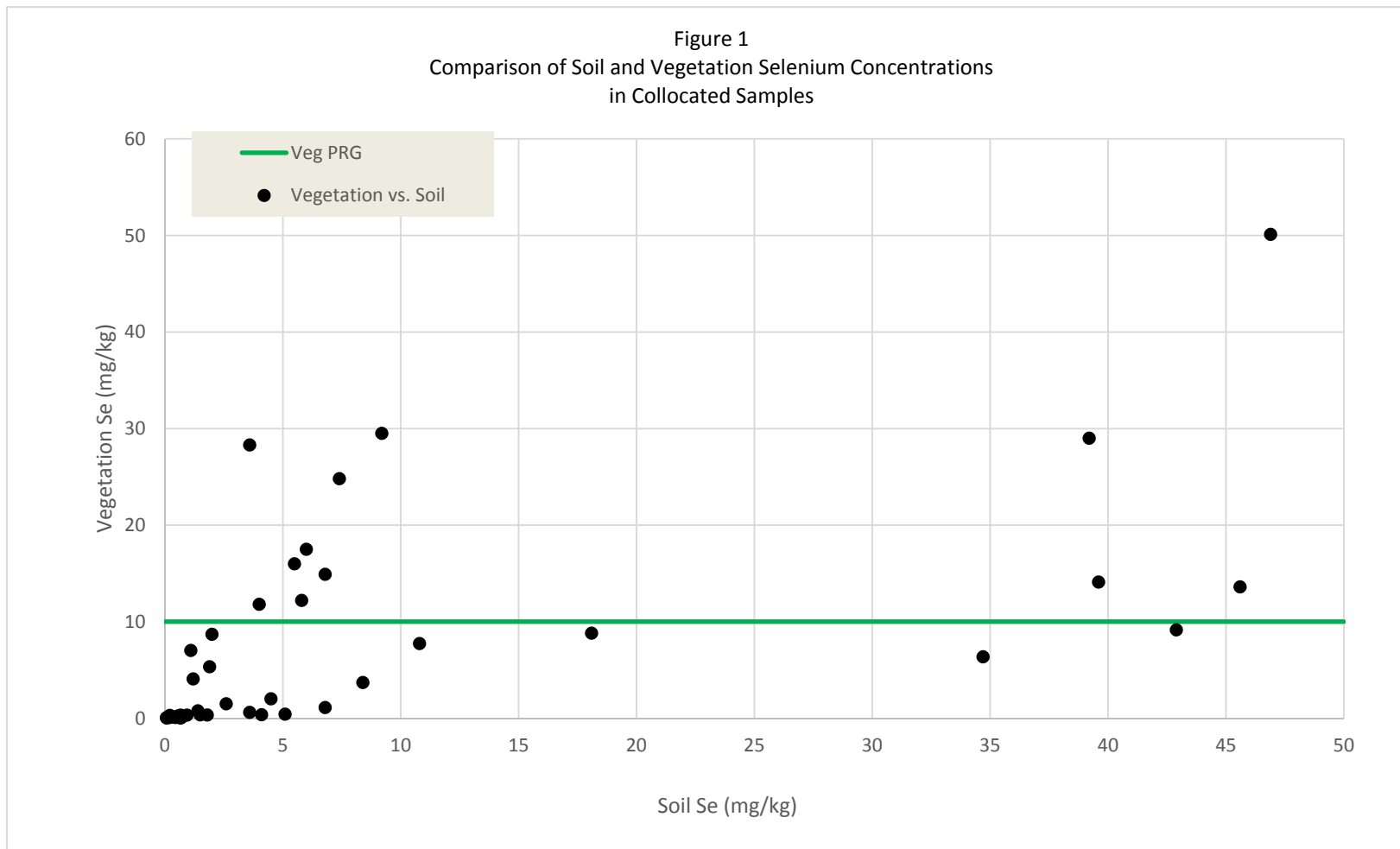2 - Excludes outlier small mammal samples from PCO-06

TABLE 16
Soil Ingestion Only PRG

Receptors	Soil Ingestion Rate (mg/kg BW/day)	TRV (mg/kg BW/day)	Soil Concentration (mg/kg)	Target HQ
Deer Mouse	0.0032	0.437	137	1
American Robin	0.0027	0.610	226	1
Mule Deer	0.0003	0.437	1457	1
Coyote	0.0009	0.437	486	1
Northern Harrier	0.0007	0.610	871	1

Note:

Assumes 100% Site Use

FIGURES

Figure 1
Comparison of Soil and Vegetation Selenium Concentrations
in Collocated Samples

FIGURE 1
COMPARISON OF SOIL AND VEGETATION SELENIUM CONCENTRAITONS IN COLLOCATED SAMPLES

J.R. SIMPLOT COMPANY
SMOKY CANYON MINE RI/FS
FEASIBILITY STUDY TECH MEMO #1

DATE: MARCH 2017

BY: JMA | FOR: ACK

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